

Appendix H

Examples of Stone Size Calculations

H-1. Problem 1

a. Problem. Determine stable riprap size for the outer bank of a natural channel bend in which maximum velocity occurs at bank-full flow. Water-surface profile computations at bank-full flow show an average channel velocity of 7.1 ft/sec and a depth at the toe of the outer bank of 15 ft. The channel is sufficiently wide so that the added resistance on the outer bank will not significantly affect the computed average channel velocity (true in many natural channels). A nearby quarry has rock weighing 165 pcf and can produce the 12-, 18-, and 24-in. $D_{100}(\text{max})$ gradations shown in Table 3-1. A bank slope of 1V on 2H has been selected based on geotechnical analysis. A blanket thickness of $1D_{100}(\text{max})$ will be used in this design. Bend radius is 620 ft and water-surface width is 200 ft.

b. Solution. Using Plate 33, the maximum bend velocity V_{ss} is 1.48(7.1) or 10.5 ft/sec. The side slope depth at 20 percent up the slope is 12 ft. Using either Equation 3-3 or Plates 37 and 40, the required D_{30} is 0.62 ft. From Table 3-1, the 18-in. $D_{100}(\text{max})$ gradation is the minimum available gradation that has $D_{30}(\text{min})$ greater than or equal to 0.62 ft. This example demonstrates the added safety factor that often results from using standard gradations to avoid the extra production costs incurred by specifying a custom gradation for every design condition.

H-2. Problem 2

a. Problem. Determine stable riprap size in a bend of a trapezoidal channel with essentially uniform flow. Bank slope is 1V on 2H and both the bed and banks will be protected with the same size of riprap. The bottom width is 140 ft, slope is 0.0017 ft/ft, and the design discharge is 13,500 cfs. Use $1D_{100}(\text{max})$ thickness and the same quarry as in Problem 1. Bend radius is 500 ft and bend angle is 120 degrees.

b. Solution. In this problem the solution is iterative; flow depth, velocity, and rock size depend on each other. Use Strickler's equation $n = 0.036 (D_{90}(\text{min}))^{0.166}$ to estimate Manning's resistance coefficient. Bend velocity is determined using Plate 33.

(1) Assume trial gradation and solve for riprap size as shown in Tables H-1 and H-2. Use uniform flow computations listed in Table H-1.

(2) Use velocity estimation and riprap size equations to obtain riprap size in Table H-2.

This example demonstrates that the increasing rock size for the three trial gradations results in increasing depth and decreasing velocity. The minimum acceptable gradation is the 18-in. $D_{100}(\text{max})$.

Table H-1
Uniform Flow Computations

Trial D ₁₀₀ (max) in.	Manning's n	Normal Depth, ft ¹	Water- Surface Width, ft	Average Velocity fps ¹	Side Slope Depth, ft
12	0.034	10.6	182.4	7.9	8.5
18	0.036	11.0	184.0	7.6	8.8
24	0.038	11.3	185.2	7.3	9.0

¹ From iterative solution of Manning's equation $Q/A = (1.49/n)R^{2/3}S^{1/2}$.

*

Table H-2
Velocity Estimation and Riprap Size

Trial D ₁₀₀ (max) in.	<u>Bottom Width</u> Depth	R/W	V _{ss} , ¹ fps	Computed D ₃₀ , ² ft	D ₃₀ (min) of trial ³ ft
12	13.2	2.74	9.9	0.59	0.48
18	12.7	2.72	9.5	0.53	0.73
24	12.4	2.70	9.2	0.48	0.97

¹ From Plate 33 using trapezoidal channel.

² From Equation 3-3 or Plates 37 and 40.

³ From gradation information given in Table 3-1.

*